A NEW APPROACH TO TREAT THE SOLID-FLUID BOUNDARY CONDITIONS IN LATTICE BOLTZMANN METHOD

Zhi-Gang Feng[1], Xiaodong Wang[2], Efstathios E. Michaelides[1]

[1]Department of Mechanical Engineering, Tulane University
zfeng@tulane.edu; emichael@mailhost.tcs.tulane.edu

[2]Department of Mechanical Engineering, Polytechnic University
xwang@poly.edu

The lattice Boltzmann method (LBM) is a numerical scheme for solving viscous fluids problem; it is originated from kinetic theory. LBM has an underlying lattice grid and represents the state of the fluid at a lattice node by a fluid particle density distribution function. Fluid particles are able to move from one lattice site to another in a discrete time steps through two essential steps: collisions and propagations. The simplicity and kinetic nature make LBM a very robust method in areas such as particulate fluid, flow in porous media, and multicomponent flow. However, the treatment of solid boundary conditions in LBM has always been a challenge subject. Almost all the previous LBM simulations apply the bounce-back rule or its variations when the solid boundary is involved. It assumes that all the incoming fluid particles that advect to the solid boundary will be reflected back towards the nodes hey came from. However, for the cases of complex solid boundaries, the bounce-back scheme results representing the physical boundary buy using a zig-zag artificial boundary; and this causes great numerical errors and instability when the solid boundary is outlined only by a small number of lattice grids. In 1970s, Peksin developed a method to solve fluid-structure interaction problems called immersed boundary (IB) method. The IB method provides a novel approach to treat solid-fluid boundary. Initially, this method was used to model the flow of blood in the heart. The flow is regulated by heart valves, which are moving boundaries immersed in the fluid. This method uses a fixed Cartesian mesh for fluid, however, for the boundary immersed in the fluid, it consists of a set of boundary points that can be either stationary or advected by fluid interaction. This method is especially suitable for the simulation of the structure in fluid, and it has been widely used in biological fluid dynamics. In this paper, we employ the immersed boundary to lattice Boltzamann method to treat the solid boundary. The no-slip boundary conditions on the solid boundary are resolved by adding a force density term into the lattice Boltzmann equation.